Strengths of the Simpson's Rule Correctors for Systematic Multipoles in the SSC

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It has recently been proposed[1] that correction of systematic multipole components of the SSC dipoles be obtained by lumped correcting elements placed at the center (C) of the SSC half cells as well as in the spool pieces near the F and D quadrupoles. The strengths per half cell of the elements are given to first order by Simpson's Rule for three-point integration ($f_F : f_C : f_D) = (\frac{1}{6} : \frac{4}{6} : \frac{1}{6})$. First order tune shifts are correctable by two orders of magnitude in this scheme. At currently projected SSC magnet and lattice parameters, correction of systematic sextupole, octupole and decupole components (b_2, b_3, b_4) is required.

The strengths of the corrector elements can be obtained from the relationship:

$$S_{n,i} l_i = f_i B_0 \overline{b_n} L_B \qquad (1)$$

where B_0 is the dipole field, $\overline{b_n}$ is the dipole multipole content, L_B is the total dipole length per half-cell (100 m), l_i is the $i = F, D$, or C corrector length, f_i is the relative strength parameter and $S_{n,i}$ is the multipole field strength of the $(2n+2)$-pole corrector.

The values of the corrector strengths depend on the actual multipole content, which is not precisely known at this time. Calculations and extrapolation from Tevatron experience can obtain some guidelines for these strengths.[2] Extrapolation from the Tevatron obtains $\overline{b_3} = -0.14 \times 10^{-4} \mathrm{cm}^{-3}$ and $\overline{b_4} = -0.33 \times 10^{-4} \mathrm{cm}^{-4}$ or -0.14 and -0.33 'units', where a unit is 10^{-4} at 1 cm. Persistent currents have been calculated to impose 0.30 units of decupole at SSC injection field.

In Table 1 we present corrector strengths based on these error fields with an added margin of safety (correction of 0.5 units for octupole and correction

of 1.0 units of decupole at injection and 0.5 units at 20 TeV (6.6 T)). Note that $l_i = 1.0$ m has been chosen as the reference corrector length.

For sextupoles, the recommended correction scheme differs from the Simpson's Rule values.[3] F and D correctors alone are sufficient to correct the first-order sextupole nonlinear tune shifts and second-order tune shifts are important. For second-order effects, an "equal-weights" correction is slightly preferable to Simpson's Rule and that rule is used in Table 1. A persistent current strength of $\overline{b_2} \sim 5$ units at injection is expected; the center corrector is helpful in reducing second-order tune shifts to tolerance levels. Corrector strengths for 6 units are included in table 1.

At full energy, sextupole field should be substantially smaller ($\overline{b_2} \sim 1.0$ units) and aperture requirements may be reduced. Correction by end correctors alone is then adequate; also corrector implementation is simplified by reducing the center corrector strength.[4] Sextupole correction at full energy is thus obtained by end correctors only and the required strengths for 1.5 units are included in Table 1. The end correctors must correct chromaticity as well as $\overline{b_2}$. The strength requirements for that are shown in Table 1; they should be added to the sextupole correction to obtain total corrector strengths. Note that to get the correct total strengths the relative signs must be correctly chosen.

Table 1 summarizes corrector requirements. These should be rescaled and modified as magnet properties become more precisely known, and the safety margins may be changed.

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References

1. D. Neuffer, SSC-N-339, May 19, 1987.

2. D. Neuffer and J. M. Peterson, SSC-113, presented at the 1987 Particle Accelerator Conference, Washington, DC, March, 1987.

3. D. Neuffer, SSC-132, June, 1987.

4. P. Limon, private discussions, June 1987.

Table: Simpson's Rule Corrector Strengths

Corrector strengths. The reference corrector length is $l_i = 1.0$ m. Corrector strengths S_n are in units such that $B_y(x,0) = S_n x^n$.

Correction Multipole and Conditions	F and D Corrector Strengths (per cell)	C Corrector Strength (per half-cell)
Octupole, $\overline{b_3} = 0.5$ units $B_o = 0.33$ T (1 TeV injection)	550 T/m^3	1100 T/m^3
Octupole, $\overline{b_3} = 0.5$ units $B_o = 6.6$ T (20 TeV)	1.1×10^4 T/m^3	2.2×10^4 T/m^3
Decupole, $\overline{b_4} = 1.0$ units $B_o = 0.33$ T (injection)	1.1×10^5 T/m^4	2.2×10^5 T/m^4
Decupole, $\overline{b_4} = 0.5$ units $B_o = 6.6$ T (20 TeV)	1.1×10^6 T/m^4	2.2×10^6 T/m^4
Sextupole, $\overline{b_2} = -6.0$ units $B_o = 0.33$ T (injection)	100 T/m^2	100 T/m^3
Sextupole, $\overline{b_2} = -1.5$ units $B_o = 6.6$ T (20 TeV)	1000 T/m^2	0
Sextupole, Chromaticity Correction $B_o = 6.6T$ (20 TeV)	400 T/m^2 (F) -800 T/m^2 (D)	0